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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

J. Maeritz

Serial No. 10/706,612

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For METHOD, PREPARATIONS, COMPUTER-READABLE STORAGE WAREHOUSE AGENT AND COMPUTER PROGRAM ELEMENT FOR THE CONTROL OF MANUFACTURING PROCESS OF A MAJORITY OF PHYSICAL OBJECTS

Examiner: Unknown

Group Art Unit No. Unknown

SUBMISSION OF SUBSTITUTE SPECIFICATION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Applicant hereby submits a substitute specification to replace the specification currently on file with the Patent Office. A redlined version and clean version incorporating the redlined changes are both attached. The substitute specification includes no new matter.

Respectfully submitted,

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~~Description~~

Method, device, computer-readable storage medium and computer program element for the monitoring of a manufacturing process of a plurality of physical objects

FIELD OF THE INVENTION

[0001] The invention relates to a method, a device, a computer-readable storage medium and a computer program element for the monitoring of product quality data in a manufacturing process.

BACKGROUND OF THE INVENTION

[0002] In the manufacture of wafers with highly integrated semiconductor chips, the ever-increasing miniaturization of the structures on the semiconductor chip are responsible in particular for imposing ever greater requirements on the production installations and manufacturing processes used for the manufacture of the semiconductor chips. The stability and reproducibility both of the production installations and of the manufacturing processes decisively influence the yield and productivity during semiconductor chip production. Even small deviations from a prescribed form of behavior of a chip production installation during production can lead to considerable worsening of the yield (i.e. a considerable increase in the defect rate of the semiconductor chips manufactured).

[0003] To ensure the quality of the manufacturing process and the quality of the wafers, the wafers must be subjected to test measurements once processing of them has been completed. To monitor and assess the manufacturing process completely, it would be necessary to test each individual wafer which has been produced by means of the manufacturing process and subsequently to assess the quality of the wafer. However, this is not possible due to the time- and cost-intensive test measurements for determining the quality of the wafers.

[0004] According to the prior art, this is resolved by statistically (i.e. randomly selecting individual wafers as random samples from a lot of wafers after completion of the manufacturing process). This method is usually referred to as a "Statistical Process Control" (SPC) method. Test measurements are subsequently carried out on this random sample. Within the application, these test measurements are also referred to as SPC measurements. On the basis of the results of the test measurements, a statement is then made concerning the quality of all the wafers of the lot. It is assumed here that wafers which are representative of the overall lot are selected. For example, any two wafers of the lot are selected. It is assumed that the quality of the overall lot will then fluctuate about the measured values of the quality. The values determined in this way are used both for the determination of the cp value, which is a statement of the range of a distribution of the measured values, or in other words a measure of the smallest possible proportion of defective units (wafers) in the process that is expected when the position of the distribution is centered. The values are also used for the determination of the cpk value, which is a value which indicates how centrally the distribution of the measured values lies in relation to a prescribed specification, or in other words a measure of the expected proportion of defective units in the process.

[0005] Although this procedure has the advantage that it can be carried out quickly and at low cost, it has the disadvantage that in the case of this procedure the ascertained quality of the wafers is subject to chance events. If in the arbitrary selection of the random sample a wafer of poor quality is taken, the poor quality is ascribed to the overall lot. Conversely, it may also be the case that an overall lot is classified as meeting specific quality criteria if by chance an item of high quality, i.e. a wafer that has been processed with above-average quality, is taken for the test measurement for determining the quality.

[0006] The fluctuations which are caused by the random selection also have the effect that, in the method according to the prior art, the determination of the cp value and of the cpk value is also only possible unsatisfactorily.

[0007] Consequently, according to the prior art, quality values of wafers and of the manufacturing process are subject to statistical fluctuations about which no statements can be made. The statement depends on the random selection of the tested wafer. Consequently, the cp values of the manufacturing process and the cpk values of the manufacture are also subject to uncertainties. To obtain statements concerning the soundness of the quality assessment or to make the quality assessment statistically more significant, the number of wafers that are subjected to the test measurement would have to be increased.

[0008] C.K. Lakshminarayan in an article "Overview of outlier methods in SC Manufacturing" (TI Technical Journal 1998) discloses an overview of methods for detecting outliers in semiconductor manufacture is given.

[0009] US Patent 5,422,724 discloses a method for reducing targeting errors encountered when trying to locate contaminant particles on a wafer in a high-magnification imaging device.

[0010] German Patent Publication DE 198 47 631 discloses a quality management system in which a data processing unit processes a data value measured by a defect inspection device, such as for example the number of defects, a surface area of each defect, an equivalent diameter of the surface area, etc., in such a way that index values are calculated as processed data values and used by a judgment unit as a basis for judging whether or not further testing is to be carried out.

[0011] The invention is based on the problem of increasing the informative value of the quality monitoring measurement of a lot of wafers.

[0012] ~~The problem is solved by the method and the device for the monitoring of a manufacturing process with the features according to the independent patent claims.~~

[0013] In the case of a method for the monitoring of a manufacturing process of a plurality of physical objects, an analysis is performed by using values of at least one process parameter of the manufacturing process of the physical object. As a result of the analysis, when they satisfy a certain selection criterion, physical objects are marked in such a way that the associated physical objects can be taken as a random sample for the monitoring of the manufacturing process (i.e. SPC measurements can be carried out on the sample for monitoring the quality of the physical object).

[0014] A process parameter is to be understood in this connection as meaning a parameter of a manufacturing process of a physical object. These include, for example, in the manufacture of a wafer the misalignment (i.e. the inaccuracy of the positioning of a wafer in a machine, or in other words a deviation of an actual position of the wafer in the machine from the prescribed position of the wafer in the machine), within a positioning step, the temperature during a process step, the gas flow during a process step, the time duration of a process step, the pressure prevailing during a process step, generally all valve positions, a wafer carrier speed and a wafer carrier contact pressure. Other process parameters in lithography are, for example, various alignment variables, a focusing or a dose. These process parameters are constantly measured during the manufacturing process and are available for an analysis.

[0015] The analysis may be a statistical analysis. It may, however, also investigate individual values or evaluate simple statements, for example whether or not a physical object satisfies a certain requirement (good - no good).

[0016] The device for the monitoring of a manufacturing process of a physical object has at least one processor, which is set up in such a way that the method steps described above can be carried out.

[0017] In a computer-readable storage medium, a processing program for the monitoring of a manufacturing process of a physical object is stored, which

processing program has the method steps described above when it is run by a processor.

[0018] A computer program element for the monitoring of a manufacturing process of a physical object has the method steps described above when it is run by a processor.

[0019] The invention can be realized both by means of a computer program, i.e. software, and by means of one or more special electrical circuits, i.e. in hardware, or in any desired hybrid form, i.e. by means of software components and hardware components.

[0020] The invention has the advantage that, by means of the analysis of the process data, a selection criterion is provided for a random sample selection by means of which a random sample which is representative of the overall lot can be determined. It is not the case as in the prior art that a random sample is arbitrarily taken from the lot and subjected to an SPC measurement, but instead those random samples of a product quality typical of the overall lot are selectively taken. The method consequently allows active random sample selection on the basis of process data. By means of the method, consequently a random sample on which an SPC measurement is carried out for ascertaining the quality can be determined, and consequently the overall lot can be characterized in an improved way. The informative value of the quality testing is increased. It is also possible by means of the method according to the invention for the selection of the random samples to be automated.

[0021] Preferred developments of the invention emerge from the dependent claims. The further refinements of the invention concern the method and the device for checking the manufacturing process of a physical object, the computer-readable storage medium and the program element.

[0022] The physical object is preferably a wafer.

[0023] The invention is well-suited in particular in the case of wafer manufacture with its extremely high number of process steps, with very high

requirements on the accuracy of the setting of the process parameters, since an automated, improved quality control is realized in a simple way for the first time in this area.

[0024] In a preferred development, the analysis is a statistical analysis.

[0025] Furthermore, in the case of the method according to the invention, the values of the at least one process parameter are measured when the physical object is being manufactured.

[0026] According to one refinement, the physical objects of the random sample are subjected to a quality checking measurement for checking the quality of the respective physical object.

[0027] For ascertaining the variation of the qualities of the physical objects, a physical object for which the value of the at least one process parameter has a prescribed difference from the random sample is preferably additionally subjected to a quality checking measurement.

[0028] By means of this additional quality checking measurement, it is possible in a simple way to determine the variation of the distribution of the product qualities of the physical objects of a lot by means of a single additional measurement. The prescribed difference is preferably the maximum difference occurring in the distribution of the process parameters. Preferably, the prescribed difference is a difference which corresponds to a 1σ difference of the distribution.

[0029] The analysis preferably comprises the ascertainment of the median of the values of the at least one process parameter.

[0030] The median of a distribution of a process parameter is particularly suited for characterizing a lot, since with it values of the process parameter which deviate strongly from the other measured values of the process parameters have no effects. Wafers which produce a value close to the median of the distribution for the process parameter concerned characterize the lot concerned particularly well. As a result, the informative value of a quality checking measurement is increased.

[0031] The analysis may comprise the ascertainment of the arithmetic mean value of the values of the at least one process parameter.

[0032] The arithmetic mean value likewise characterizes the distribution of the process parameters measured during the manufacture of wafers of a lot. Furthermore, it can be calculated more easily and quickly than the median.

[0033] By means of the method according to the invention, a selection criterion which serves the purpose of determining representative wafers of a lot is provided. For this purpose, the median of a distribution of measured values of a process parameter is preferably determined when the individual wafers of a lot are being manufactured. Wafers for which the process parameter concerned has during their manufacture a value close to the median of the distribution of all the measured values of the process parameter characterize the lot concerned particularly well. As a result, the informative value of a quality checking measurement is increased.

[0034] If a range of fluctuation of the quality distribution is also to be additionally determined, then not only a random sample which characterizes the median or the arithmetic mean value of the distribution is investigated but also a random sample which characterizes the border of the distribution of the values of the corresponding process parameter. Alternatively, the range of fluctuation may also be determined directly from the distribution of the values of the process parameter. This procedure has the advantage that both the mean value and the range of the quality distribution can be determined directly by means of a single time- and cost-intensive measurement on two wafers. Furthermore, the method according to the invention has the advantage that it is also possible to dispense entirely with the laborious SPC measurements for determining the quality of the wafers if it is evident by means of the process data recorded and statistically evaluated that no deviations have occurred since the last quality measurement that was carried out for a wafer of the same manufacturing process.

[0035] Consequently resulting as advantages of the method according to the invention are a reduction in the number of random samples on which quality

measurements have to be carried out to obtain the same statistical informative value. Consequently, a reduction in the machine capacity requirement, greater automation of the random sample selection and improved product control are achieved. A further advantage is a greater credibility or reliability of the determination of cp and cpk values of the manufacturing process. This greater reliability of the determination results in turn in the possibility of a more specific intervention in the production sequence, in particular an improved possibility of controlling the course of the process.

[0036] Even though the invention is explained in more detail below on the basis of the example of a monitoring method of a wafer manufacturing process, it is pointed out that the invention is not restricted to a wafer manufacturing process but instead can be used in all monitoring methods for manufacturing processes in which process parameters are recorded in the manufacturing process for manufacturing a physical object, for example also in the pharmaceuticals industry in the manufacture of pharmaceutical products.

BRIEF DESCRIPTION OF THE DRAWINGS

[0037] An exemplary embodiment of the invention is explained in more detail below and represented in the figures, in which:

[0038] Figure 1 shows a block diagram in which the general organization of a chip production installation is represented;

[0039] Figure 2 shows a diagram of a chip production installation, with the complex material flow, i.e. the path of a wafer/lot, through the chip production installation and the associated complex process steps being represented;

[0040] Figure 3 shows a block diagram in which the process data flow when producing a wafer/lot is represented; and

[0041] Figure 4 shows a distribution of values of a process parameter which is used as a selection criterion in a statistical analysis.